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# CENTRIFUGAL PUMPS[1]

## By E. C. York

The trend of the times in power plant equipment shows plainly a movement from the reciprocating toward the rotary type of machine, whether turbine, motor, blower or pump. The centrifugal pump is one of the important developments in this evolution. Its low initial cost, small repair charges, durability, and high pumping elasticity, compel instant recognition. But if there is one machine which demands a full knowledge of its peculiar limitations, it is the centrifugal. A single pump used at constant speed for a wide range of capacity and lift is inefficient and unreliable, for the centrifugal pump gives its best results only when intelligently designed for each specific condition of operation, in accordance with the results of years of careful experimentation and consequent improvement. This evolution enables the manufacturer to guarantee better results than have hitherto been practicable, particularly as regards the multi-stage or high-lift pumps, which, as now made, are adaptable for many purposes not hitherto considered the field of centrifugal pumps. By reason of compactness, elasticity and high power, they afford a solution of pumping problems perplexing many engineers and their use makes it possible to materially reduce pumping costs.

The first centrifugal pumps had impellers with single radial wings, and these have developed into the more efficient enclosed or shrouded impellers. The combination of two or more separate centrifugal pumps in series, each discharging into the suction of the succeeding one, is not new, and very satisfactory results have been obtained for some time with this arrangement. It does away with the division sleeve between the first and second stage impellers, which is a source of a very large percentage of loss, for this sleeve becomes worn rather rapidly. There is no way to take up this leak except to remove the sleeve and replace it with a new one with new bushing, which at the present cost of bronze metal is a somewhat expensive job.

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[1] Read before the Minnesota Section April 21, 1917.

When purchasing a centrifugal pump there are five points of prime importance which every buyer should investigate most thoroughly:

1. Reliability of the pump in service.
2. Efficiency, including provisions for maintaining the original efficiency.
3. Life of the pump, or its ability to resist wear and corrosion, and the ease and cost of repairs when deterioration occurs.
4. Accessibility of all internal parts and ease with which inspection or repairs can be made without special tools.
5. Methods of manufacture, reliability of guarantees, accurate test and general service given by the pump manufacturer.

It is quite evident that several of these factors are in a measure dependent on others, and also that a pump to give the best possible results must combine all five of them. In the selection of hardly any other class of mechanical equipment do all these considerations need more careful attention on the part of the purchaser than in the case of pumps, for the reason that a machine handling water or other liquids must resist not only the usual mechanical wear but also the corrosive and erosive action of the liquid.

Reliability of operation and a constant and adequate supply of water are of great importance in any water supply system. It is therefore essential that the machine be one that will operate continuously without shut-downs or delays from mechanical troubles, and one that will not require constant and expert attention on the part of the operators. In the design, the question of reliability should be given first consideration, and each and every part should be so made that its operation is certain and dependable. The bearings should be large and carefully made, and the arrangement for lubrication should be given particular attention. Balance, both mechanical and hydraulic, should be adequately provided for in order to avoid the gradual deterioration always resulting where there is vibration. All parts of the machine should be made of such materials and of such strength that they are rugged and suitable for continuous operation for long periods.

The efficiency of a pump, or in fact of any machine, is of importance. The life of a pump is measured not only by its ability to resist wear and deterioration but also by the ease and convenience with which it may be repaired and thus restored to its original efficiency. High efficiency maintained for a short time is of no particular value, as true economy is a matter not only of the initial efficiency, but also of the ability of the machine to maintain this efficiency, and of the ease, convenience and cost with which the owner can re-establish the efficiency after the machine has been in operation for such time as necessarily causes parts to become worn or damaged. The question of accessibility is thus coupled with that of efficiency, for the reason that the machine that is easily accessible is more likely to be inspected from time to time by the operator, so that its interior condition will become known.

The design, workmanship and materials employed in a pump should be such that the original efficiency will be maintained for the longest possible period. For this reason, the engineer should not recommend cast iron impellers, because such impellers are corroded rapidly and wear much faster than the bronze impeller, resulting in a marked decrease in efficiency. As the working member of the pump the impeller exercises the greatest influence upon the efficiency. It must be properly designed, with correct surfaces and smooth finish, and it must be of material which will withstand wear and maintain the original form and smoothness. The type used in centrifugal pumps should be the inclosed or shrouded impeller, in which the blades are located between side plates, forming inclosed passages.

The type of wearing ring is also of great help in maintaining the original efficiency. The greatest leakage occurring in a centrifugal pump is from the discharge chamber to the suction chamber, between the impeller and the casing. Leakage at this point is not ordinarily detected, even when excessive, and in many pumps, causes a considerable reduction in the pump capacity and efficiency. Ordinarily this joint is formed between cylindrical surfaces concentric with the shaft; the leakage path is therefore straight and presents little resistance to the flow, and the clearance space discharges as much water as would an ordinary plain orifice of the same area subjected to the same pressure difference. The engineer should realize the great practical advantages to be secured by reducing the leakage in centrifugal pumps as much as possible.

Very desirable results have been obtained by the labyrinth type of division rings, consisting of two removable rings, one attached to the pump casing and the other to the revolving impeller. Each ring should be made to standard gages so that it can be replaced without fitting. The intermeshing grooves form a labyrinth, or tortuous passage, through which the water must pass in order to escape from the discharge to the suction chamber. The many bends in the path of the water create additional resistance to its passage, which, with the greater absolute length of the path, greatly reduces the leakage as compared with that with straight rings. The rings should be of bronze, the same material as the impeller.

Manufacturers have abandoned the use of diffusion vanes, as it was found that they deteriorate rapidly, which results in marked decrease in efficiency. They greatly complicate the interior of the pump, introduce a number of separate pieces and internal joints, rapidly become worn and eroded, particularly at the tips (which should be finely formed) and are ruined by solid bodies, such as stones, sticks or gravel, jamming between the tips of the blades and the pump impeller.

Efficient, reliable and accurate methods of manufacture by a builder of centrifugal pump equipment are of value to a purchaser in many ways. The essence of the matter is that high grade machines can be produced only by a shop using high grade methods, tool equipment, inspection and testing. Neglect of these vital matters may entail heavy expense and great annoyance later, which will far offset any possible saving in first cost. High grade workmanship and materials are not necessary for the successful initial mechanical operation of a centrifugal pump, but they are essential to long life and maintenance of efficiency and are thus of great importance in future years.

In 1910, the management of the Minneapolis water department decided to increase its pumping capacity. To this end, a thorough study was made of different types of pumps. The Minneapolis General Electric Company submitted a proposition to furnish electric power for an electrically driven pump on an "off the winter peak load basis," which included the months of November, December, January and February only, at a flat rate of $4 per 1,000,000 gallons pumped to the reservoir against a total head of 240 feet, with a combined motor and pump efficiency of 72 per cent.

Largely on account of this offer, the Water Department asked for bids on two 20,000,000 gallon two-stage electrically driven centrifugal pumping units, and also on one 20,000,000 gallon vertical triple expansion pumping engine. The bids received on the triple expansion engine varied from $88,000 to $106,000. The Henry R. Worthington Company's bid of $28,665 was accepted for two 20,000,000 gallon electrically driven, two-stage pumps of the single casing type. The contract specified that each two pump was to be driven by a 1200 horse-power, 60-cycle, three-phase, 2200-volt, slip ring induction motor, with an efficiency on full load of at least 94 per cent. The rise in temperature of any part of the motor, after a full load run of twenty-four hours, should not be more than 40°C. The combined pump and motor efficiency was guaranteed at 75 per cent.

The Minneapolis General Electric Company signed a ten year contract to furnish power at the price mentioned. The two pumps were turned over to the city in April, 1912, and have been in constant service since, except, of course, for the necessary time for repairs. The pump at the Northeast Station has been running three years without a single shut-down for repairs and with only about 1 per cent reduction in efficiency in three years. The Camden Station pump, however, has had to be overhauled annually on account of sandy water, which causes a drop in efficiency of about 5 per cent a year. On this account it is very necessary to make provision for renewing or repairing the wearing or division rings.

It has been found practicable, when the ring or the impeller becomes worn enough to require renewing, to take the impeller out, face the surface in a lathe, and renew the ring in the pump casing to fit the turned down impeller. The old set is put away for future use, and when the impeller ring is worn enough so that it will not admit of further wear, it is faced for the last time, a resurfacing ring shrunk on to take the wear, the old set of casing rings bored to fit, and practically a new pump results. The tips of the impellers do not wear enough to affect the efficiency of the pump and the casing shows no material wear.

It is worth while to give the stuffing boxes some attention, especially where there is sand or grit. The difficulty has been overcome at Minneapolis by using filtered water to seal the glands.

The operation of the centrifugal pumps has shown a considerable saving over the triple expansion units in the items of labor and maintenance. This saving was estimated at the time of installation as possibly $10,000 a year; five years' experience has proved the saving even higher than originally estimated. It amounts practically to $1.50 per 1,000,000 gallons pumped to the reservoir, or about $15,000 per year, according to present rate of consumption.